Air Quality in Oxfam Superadobe Community Building, Zaatari camp, Jordan

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1. Introduction

In collaboration with Oxfam-Jordan, the University of Bath conducted air quality monitoring in a community centre in Zaatari refugee camp over one week in May 2018. Two buildings were monitored, a superadobe (sand bag) structure and a caravan. In addition to measurements of air quality outdoors.

The monitoring consisted of two parts, airborne volatile organic compounds (VOCs) and particulate matter (PM) suspended in the air.

1.1 Volatile organic compounds (VOCs)

VOCs are organic chemicals that have a low boiling point and can evaporate from liquid to gas phase at ambient temperature. Depending on the specific VOC they can be harmful to human health in both low and high concentrations. VOCs are found in many everyday products, such as paints, cleaning and personal care products, fossil fuels, building materials, furniture and equipment. VOC concentrations are commonly measured in $\mu g/m^3$ and UK BREEAM guidelines recommends total VOC levels to be less than 300 $\mu g/m^3$.

1.2 Particulate matter (PM)

PM is dust and particulates that can originate from a number of different sources including processes involving combustion such as cooking or smoking. Inhalable particulates have different sizes that are measured in micrometres (µm) and can be up to 10µm in diameter. Fine components, which have a diameter of 2.5 µm or less, are referred to as PM2.5, and are formed by combustion. Coarse particulates PM10 occur naturally such as dust and sea salt. Exposure to particulate matter can affect both the lungs and the heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems. People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure. Long term exposure to PM10 can create respiratory problems but for mortality, PM2.5 is a stronger risk factor than the coarse particulates PM10 (WHO, 2013).

The average level on indoor exposure to PM2.5 in the UK is $3\mu g/m^3$ (Asikainen, et al., 2016). The World Health Organisation (WHO) guidelines for PM exposure can be seen in Table 1 (WHO, 2005), detailing the limits for PM2.5 and PM10 over a 24-hour period as well as an annual mean value.

Table 1: WHO guidelines for PM exposure

PM size	24 Hour Mean (µg/m3)	Annual Mean (µg/m3)
PM2.5	25	10
PM10	50	20

1.3 The studied buildings:

Two buildings were monitored, Oxfam superadobe community centre and a caravan structure community centre. In addition, outdoor particulate matter measurements were taken onsite and in a traditional house in nearby Al-Mafraq village.

Superadobe is the name used to describe buildings that are made of sand bags. Long or short sandbags are filled with moistened earth and arranged in layers or long coils. Strands of barbed wire are placed between each layer of sandbag to prevent the sandbags from sliding relative to each other and to also provide reinforcement. Stabilizers such as cement, lime, or asphalt emulsion may be added to the sandbag to improve the structural durability and strength (Calearth, 2018).

The Caravan was made of prefabricated insulated panels and a suspended timber floor.

The house in the nearby village was one storey high and built of concrete blocks. The room in which the device was placed was about 5 by 7.5 meters.

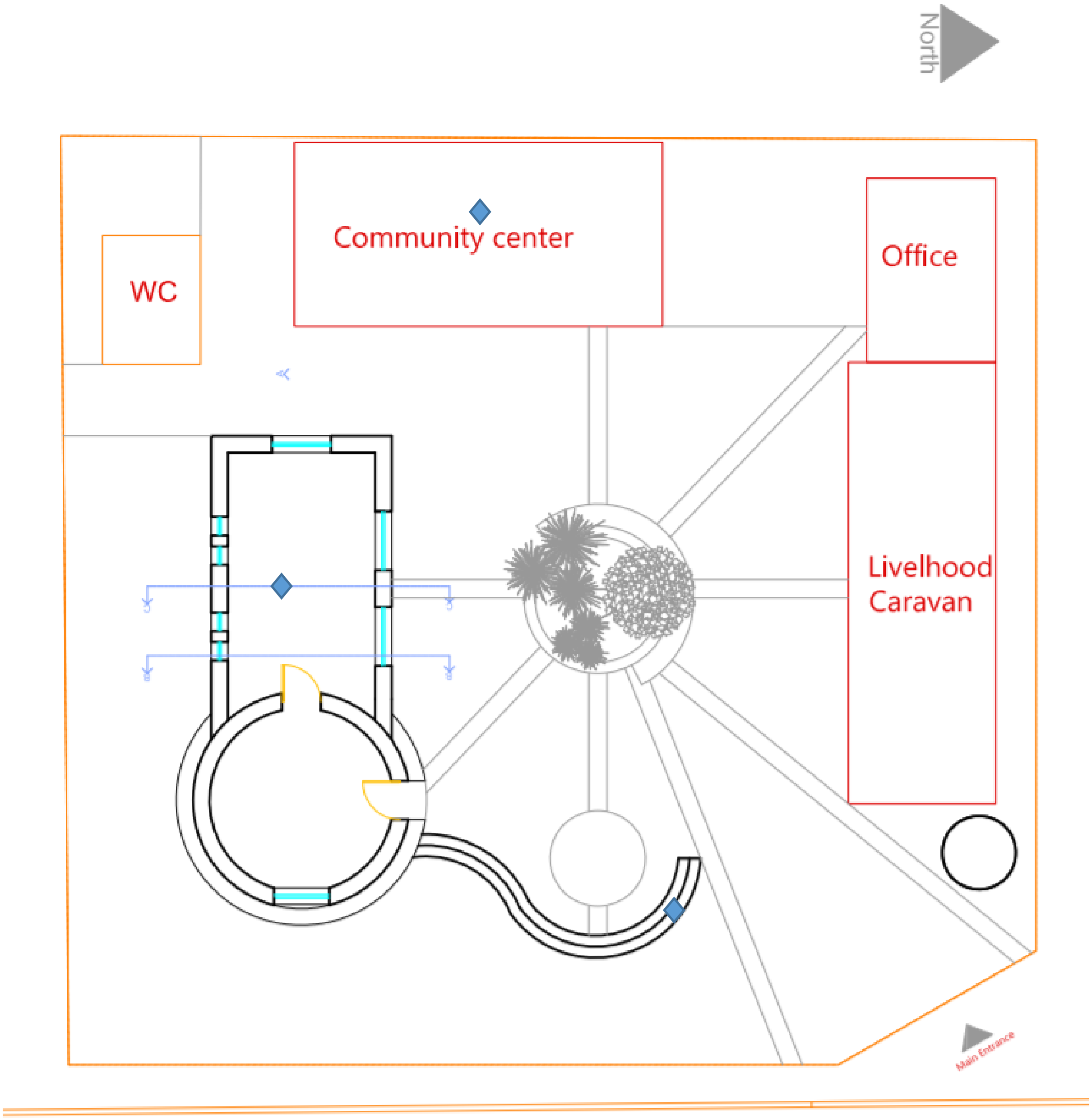

Figure 1: Site plan, location of dust monitor indicated by blue diamond. Drawing credit: Haneen Abumahfouz

Figure 2: Oxfam superadobe community centre. The weather was particularly dusty during the experiment.

Figure 3: Interior of the caravan (left), interior of the superadobe (right)

2. Methodology

2.1 VOCs monitoring

Conditioned Tenax TA tubes were supplied by Building Research Establishment - BRE[1]. These can be used for active and passive VOC sampling. Active sampling involves drawing air through the tube using a calibrated sampling pump. Typically, air is drawn for a period of time and flow rate which will not allow the tube to become totally saturated. However, in this experiment, only passive monitoring was used. Passive monitoring involved leaving an opened tube in the environment to be monitored for approximately 7 days.

[1] https://www.bregroup.com

Tubes were returned to the BRE for analysis of the airborne volatile organic compounds. As per the standard EN ISO 16000-6:2011, these are defined as chemical compounds with boiling points between 60-280°C which are trapped on the Tenax TA adsorbent tubes. The analysis was carried out in accordance with the standard EN ISO 16000-6:2011. Concentrations of total VOCs (TVOC) were analysed by thermal desorption and gas chromatography (ATD/GC) using a flame ionisation detector (FID) for quantification of compounds. The major compounds were identified by mass spectrometry (MS).

TVOC concentration is calculated as the sum of compounds eluting between (and including) n-hexane and n-hexadecane, quantified as toluene. Therefore, the TVOC concentration can differ from the sum of the individual VOCs reported.

2.2 PM monitoring

Inhalable coarse particles with a diameter between 2.5 and 10 micrometers (µm) (PM10) and fine particles with a diameter of 2.5 µm or less (PM2.5) and (PM1.0) were measured by air sampling using a TSI DustTrak DRX Desktop Aerosol Monitor. The device measures the concentration of dust particulates in an enclosure to PM10, PM4, PM2.5, and PM1.0.

Two experiments were conducted, in the first, measurements were taken inside the Superadobe structure, a communal caravan and outdoors. Each sampling was undertaken for a period of 15 minutes in each of the studied locations. This was repeated several times throughout the day between 9 am to 3 pm. In total, six sets of measurements were taken in each of the three locations, each lasting for 15 minutes.

On a separate day one measurement for 15 minutes was taken in a local house in a nearby village in addition to the caravan, the superadobe and the outdoors.

In the second experiment the dust monitor was left inside the superadobe structure for several days to measure the particulate level overnight. However, due to a loss of electrical power due to a black out there are several long gaps in the recorded data. The recording interval was 15 minutes.

The device was placed in the middle of the superadobe structure and the caravan, on a table, (approx. 1m off the floor). When measuring the outdoor particulate level, the device was also placed at 1m off the ground. Both buildings were in use during the experiments, doors and sometimes windows were frequently opened, in addition there are gaps around the doors and windows of the superadobe structure which contribute to high infiltration rates and thus dust penetration.

3. Results

TVOC concentrations are well below levels which would be regarded high and of concern (BREEAM 300 $\mu g/m^3$). The low levels are probably due to the high ventilation rates present in the buildings monitored. The table below shows the total concentration of VOCs (TVOC) in both the caravan and the superadobe building. The main VOC found in the caravan was Toluene. This chemical is commonly found in paints, fuels, wood-based materials, tobacco smoke and vehicle exhausts.

Table 2: TVOC concentration (µg/m^3) and major compounds found in both monitored locations. Concentration of the major compounds is between brackets.

Sample ID	Tube no.	TVOC (µg m^{-3})	Major compounds
Mud building	263861c	28	-
Caravan	263864c	65	Toluene (12 µg m^{-3})

The PM monitoring of the superadobe building over several days suffered from frequent and long durations of missed data due to electricity black outs. However, both day time and night time periods were covered. The data collected reveals very high levels of particulates, especially during the day when the building was in use. Results indicate that particulate levels settle down in the evening, this means that human activity such as smoking could be impacting the air quality during the day. In addition, frequent movement such as the door and windows being opened could unsettle dust on the floor leading to a significant contribution to higher PM levels during the day. Nonetheless, even night time concentration is above the recommended daily mean limits for exposure by WHO. The average PM10 level over the monitored period was 97.1 µg/m^3, twice as high as WHO daily mean limit. While PM2.5 mean exposure is three times higher than recommended levels (table 2).

Table 3: PM mean levels in the superadobe building over several days compared to WHO guidelines.

	Monitored levels over four days				**WHO guidelines for PM exposure over 24 hours**	
	PM1 (µg/m^3)	PM2.5 (µg/m^3)	PM4 (µg/m^3)	PM10 (µg/m^3)	PM2.5 (µg/m^3)	PM10 (µg/m^3)
Mean	71.0	74.9	78.6	97.1	25	50
Min	27	28	29	30	-	-
Max	506	512	523	609	-	-

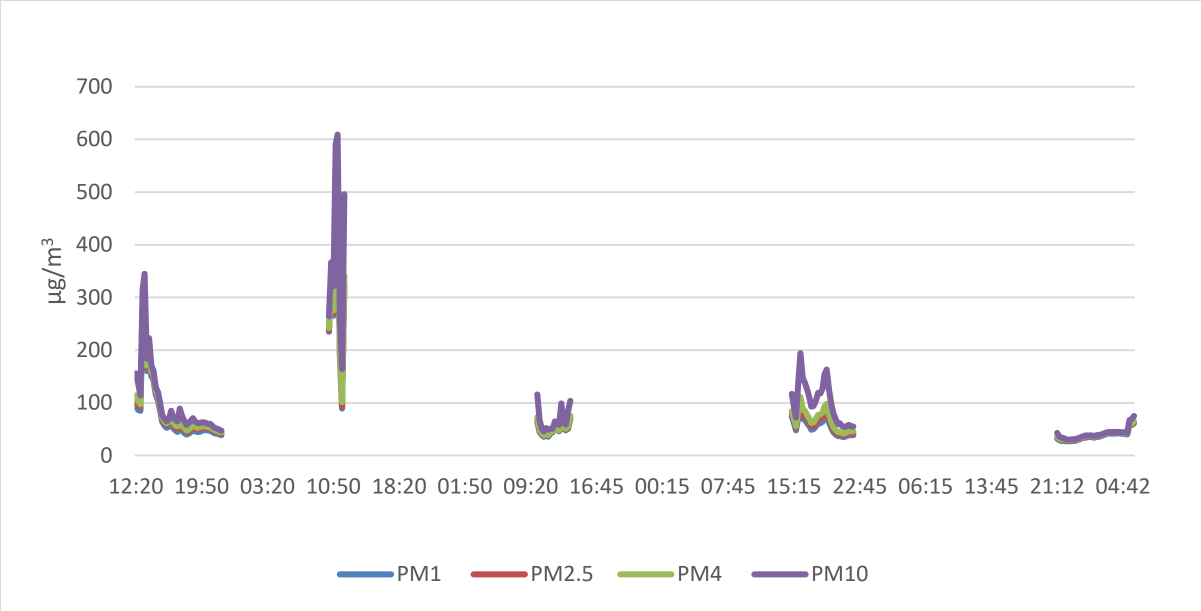

Figure 4: PM levels in the superadobe building over several days. Gaps are due to electricity blackouts.

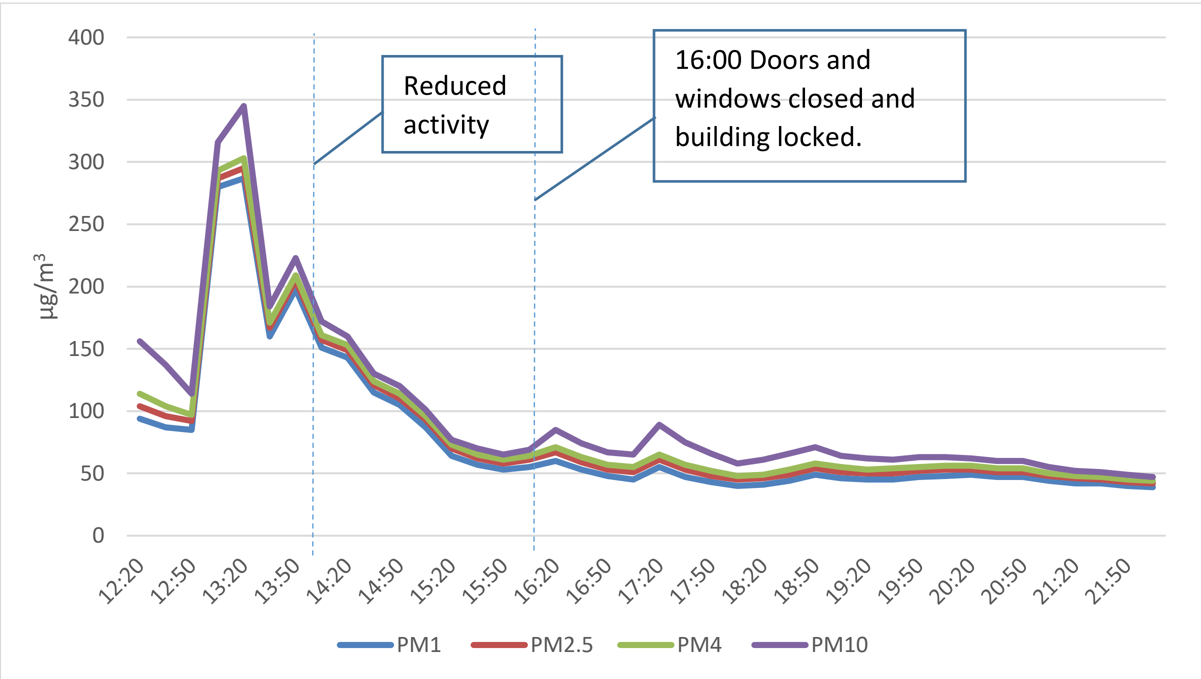

Figure 5: Particulates matter levels are lower in the evenings. This could be attributed to the building being locked and not used. However, given the presence of gaps around doors and windows, and thus high infiltration rates, it could also be accounted for by lower wind speeds.

On the 10th of May, several 15 minutes long measurements were taken in the superadobe, the caravan and outdoor to allow comparison. As seen in figure 6, measurements in all three locations appear to follow the same pattern, indicating a link to the outdoor environment.

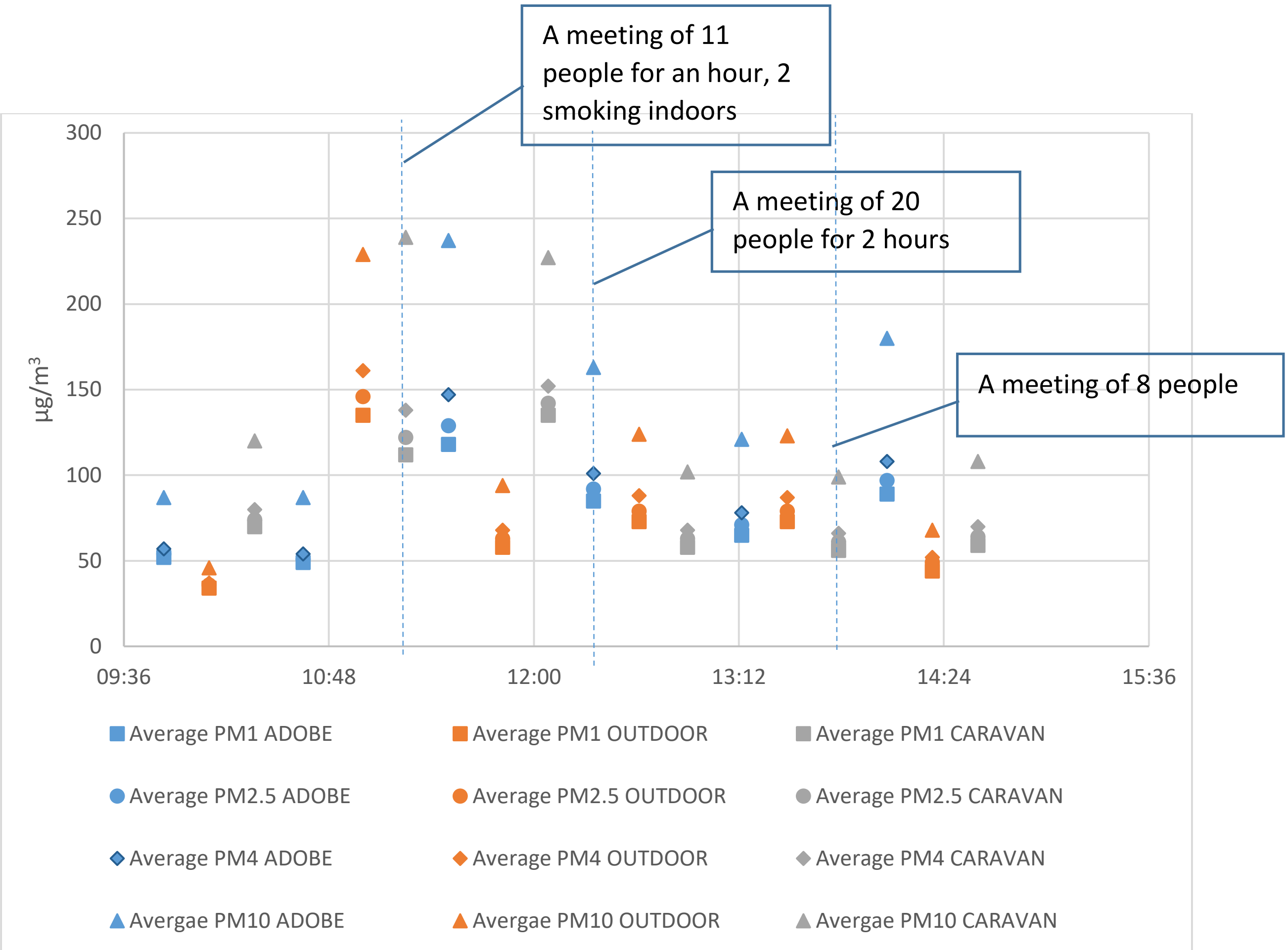

Figure 6: Mean of measurements taken inside the Superadobe structure, a communal caravan and outdoors over 15 minutes' period at several points throughout the day (10 of May 2018).

However, when considering the mean values of all measurements for each location, it results suggest that the superadobe PM levels are slightly lower compared to the caravan as is evident in figure 7. This indicates that unlike common misconceptions, earth buildings are not worse in terms of air-quality than other buildings. Figure 7 also supports our previous observation that indoor air quality is closely linked to the outdoor environment. This could have implications on the viability of relying on natural ventilation for improving thermal comfort as a compromise is needed to prevent the undesirable consequence of poor indoor air quality. This is further supported by the fact that the measurement taken in a local house indicated similar levels to those measured in the caravan and the superadobe building.

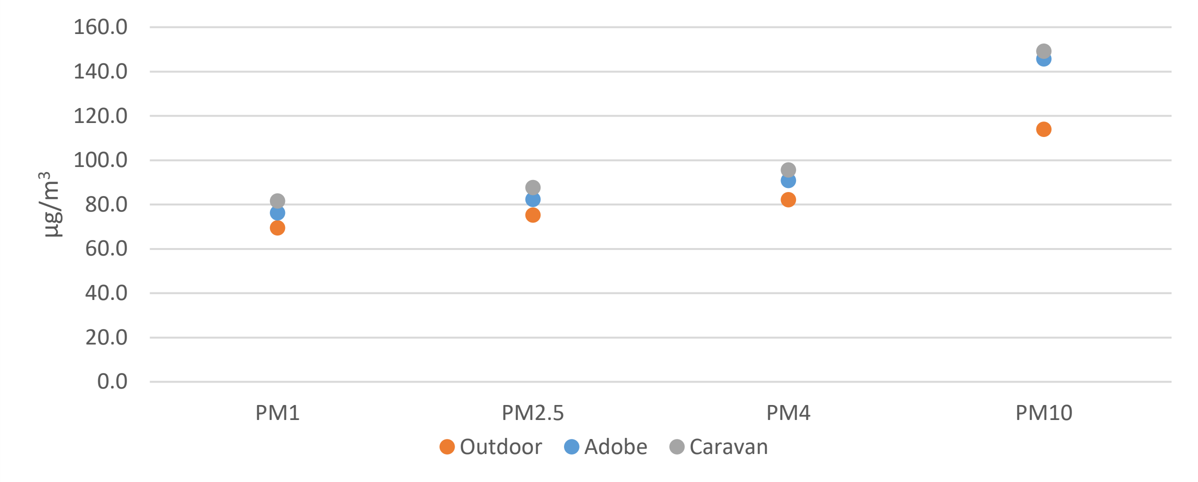

Figure 7: mean value of PM for each building measured on the 10 of May 2018.

4. Conclusions

An air quality monitoring study was conducted in May 2018 in several buildings. Two variables were studied, volatile organic compounds (VOCs) and particulate matter (PM). VOCs levels in both monitored buildings were much lower than the allowed limits in the UK, may be due to the high ventilation rate. Therefore, VOCs are not thought of to be of concern. On the other hand, PM concentrations were significantly higher than guidelines for daily exposure by WHO. It was also found that those levels were very close to outdoor levels and appeared to follow the same pattern. This means that ventilation strategies for cooling need to be re-thought to prevent dust and sand penetration. Further work will be required at a different time of the year to establish whether the high levels of PM seen were seasonal or a long term issue.

Acknowledgement

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